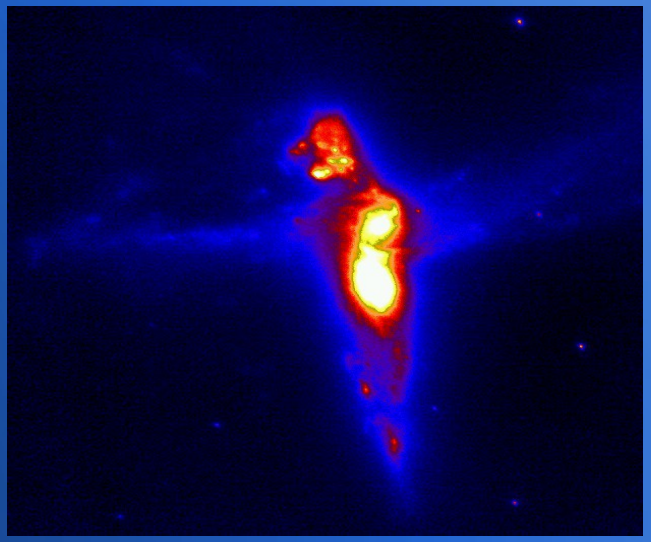
# Tracing the history of LIRGs
## *- the SUNBIRD survey*

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# Outline

- LIRG Motivation
- SUNBIRD:
  - SNe and SSCs
  - Star-formation and SF history
  - Metallicities, Kinematics
  - Gas inflow/outflows

# Known characteristics of (Ultra) Luminous IR Galaxies

As the IR Luminosity increases from 'normal' starbursts to

LIRGs $\log(L_{IR} / L\_{SOL}) > 11$ and

ULIRGs $\log(L_{IR} / L_{SOL}) > 12$ ….

- Fraction of interactions increases, distance of progenitors decreases
- Contribution of nuclear activity increases

# → Processes to study along a merger sequence

- gas spirals → starburst / ULIRG → obscured AGN → QSO → elliptical galaxy

An evolutionary sequence – how is this happening exactly ?

- Important processes:

SF triggering, gas in/outflow, SNe

AGN/starburst interplay

SMBH growth vs. host

Superwinds, other feedback

LIRGs


ULIRGs

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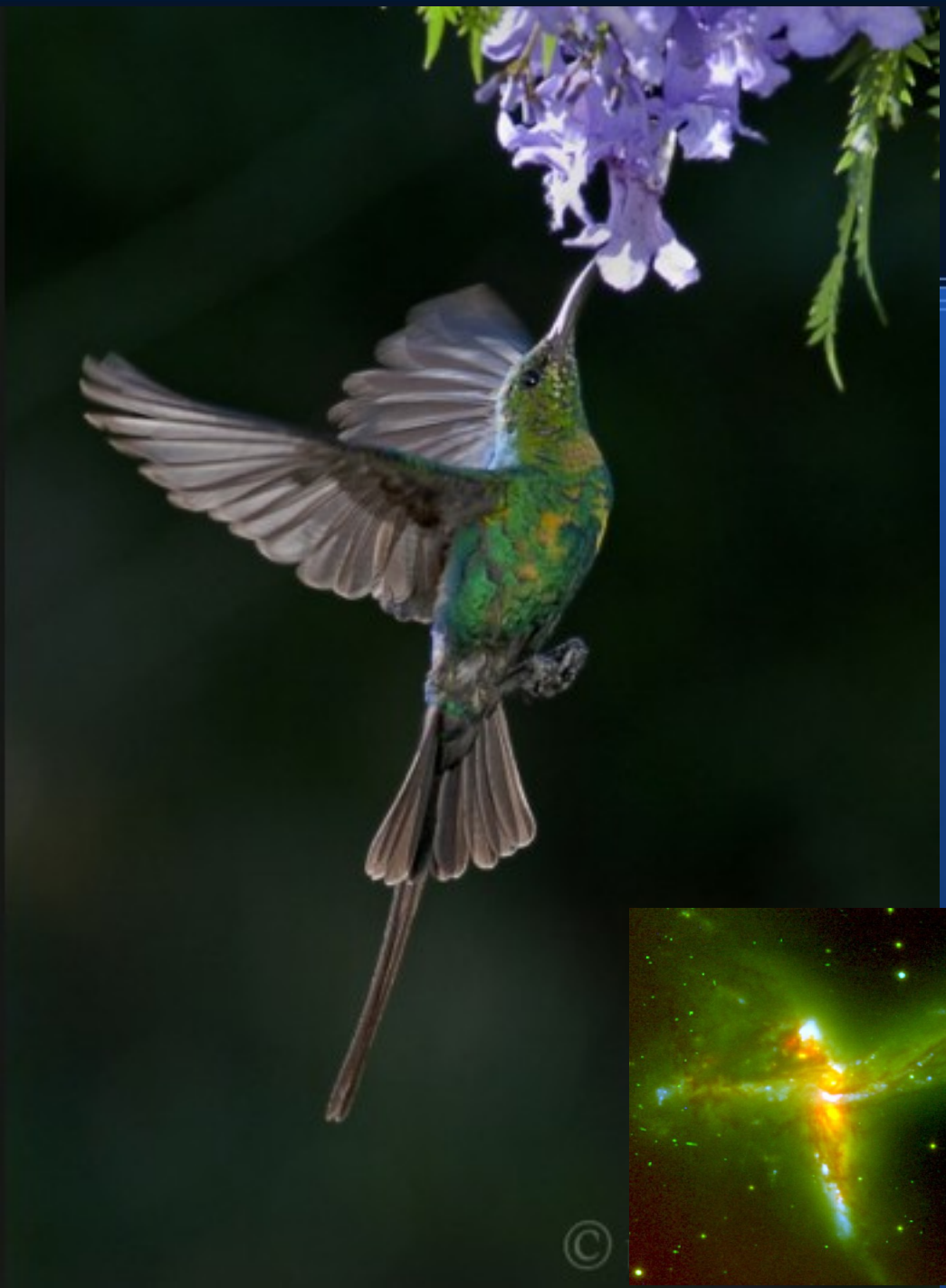
LIRGs


ULIRGs

# → Processes to study along a merger sequence

- LIRGs and ULIRGs dominate @ higher-z
- However, they are not exactly the same as locally!
- Seems like local LIRGs are more similar to distant ULIRGs (many/most? distant ULIRGs are not dominated by major mergers) cf. The “Main Sequence” of galaxies.


- *Need to study LIRGs in detail*



# *SUNBIRD* -

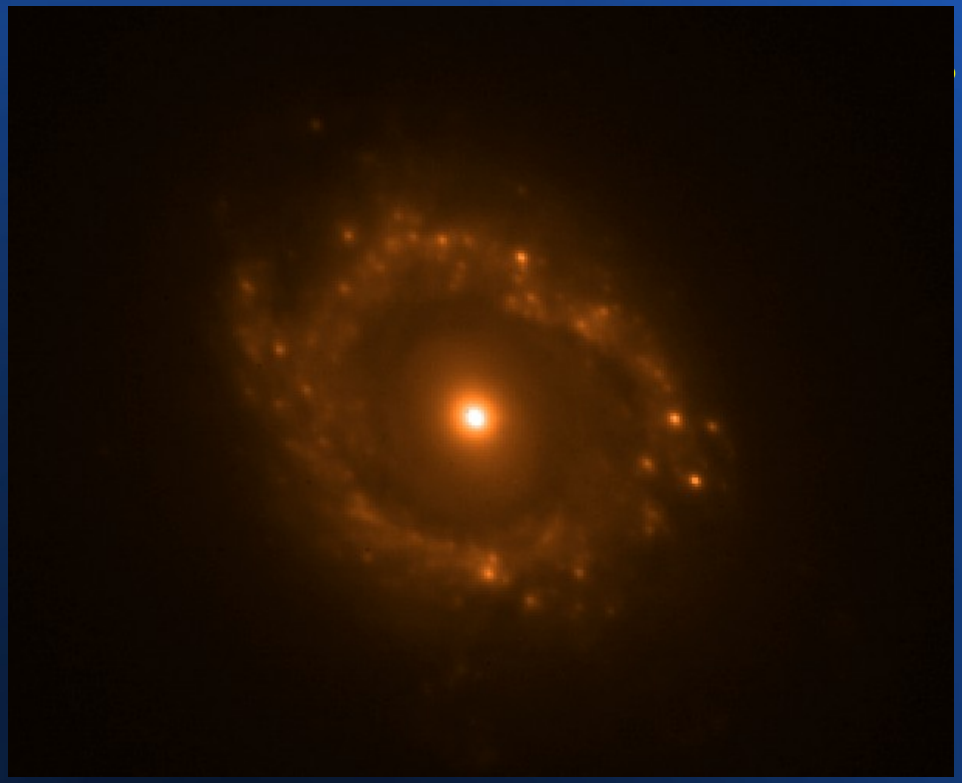
**SuperNovae & star-Bursts in the InfraRed**

- VLT/NACO
  Gemini/Altair/NIRI
  Gemini/GEMS
  **adaptive optics** programs in the NIR
- **SALT spectroscopy**
- + archival HST, Spitzer, Herschel data
  - ~ 40 LIRGS
  - ~ 40 lower lum SBs

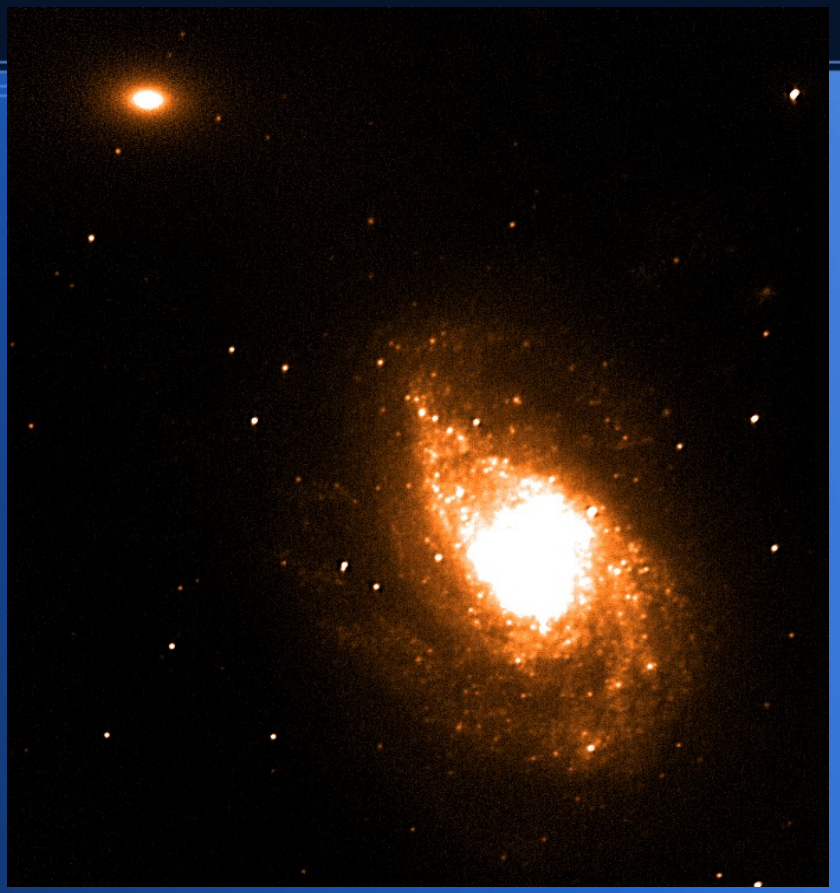
# Projects at SAAO/SALT

- Science goals:
  - Detailed physical description of LIRGs and interaction driving starbursts
  - Detailed morphologies and kinematics
  - Effects of (group) environment on galaxy transformation
  - Metallicities and extinction characteristics in galaxy interactions
  - Evolution of Super Star Clusters
  - Gas inflow/outflow and SF triggering

# Super star clusters



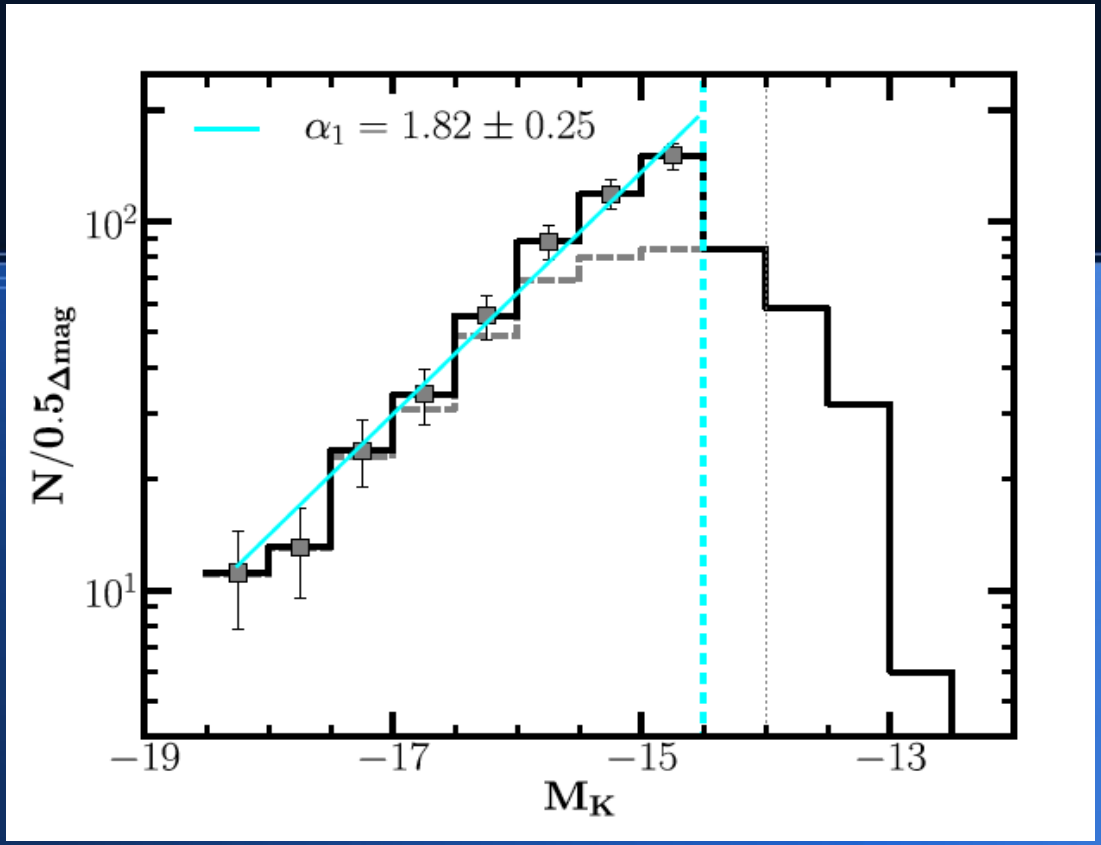
Tracers of violent SF – can study history of SF in hosts



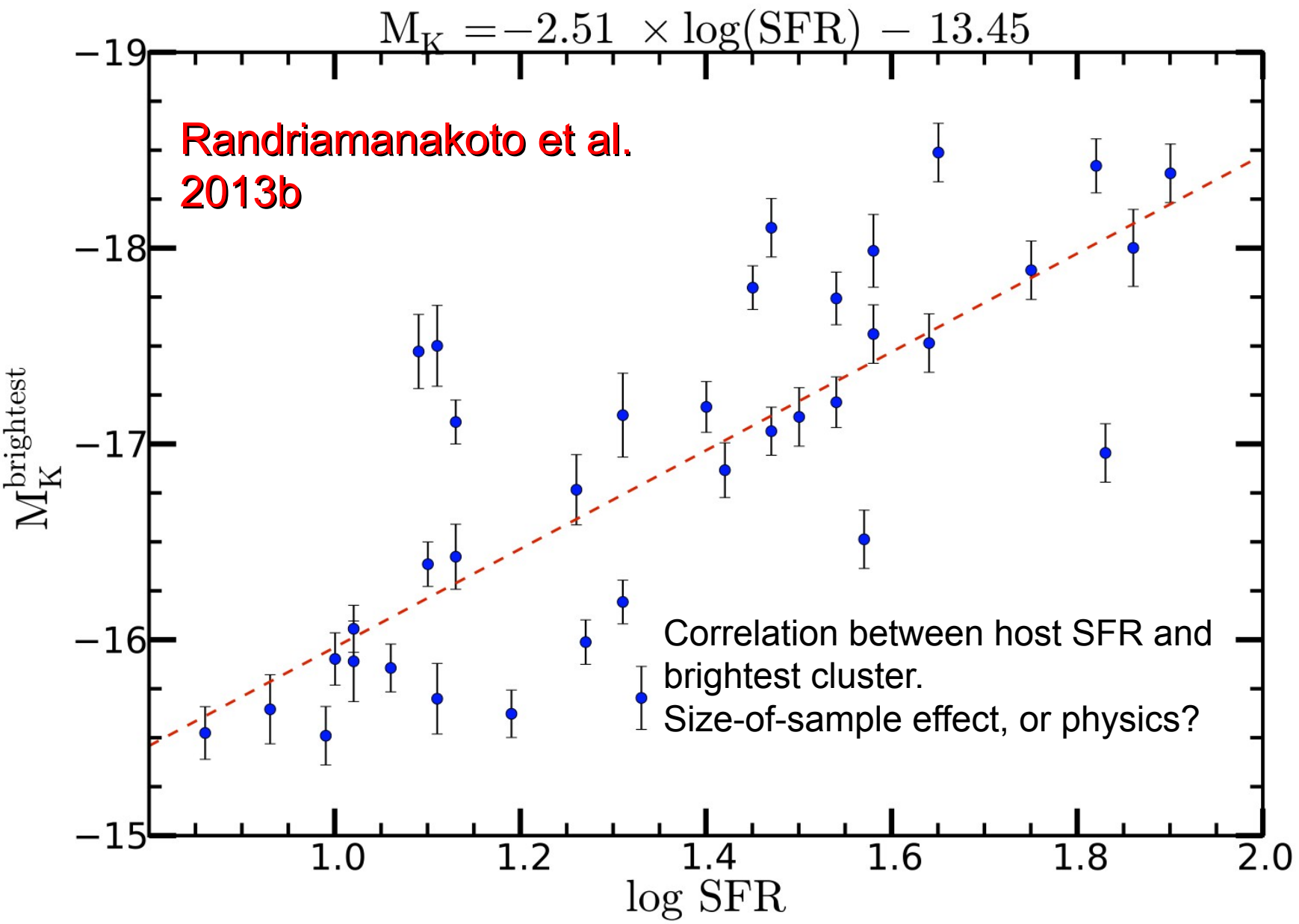
- Progenitors of Globular Clusters ?

# LF slopes

Randriamanakoto et al. 2013a



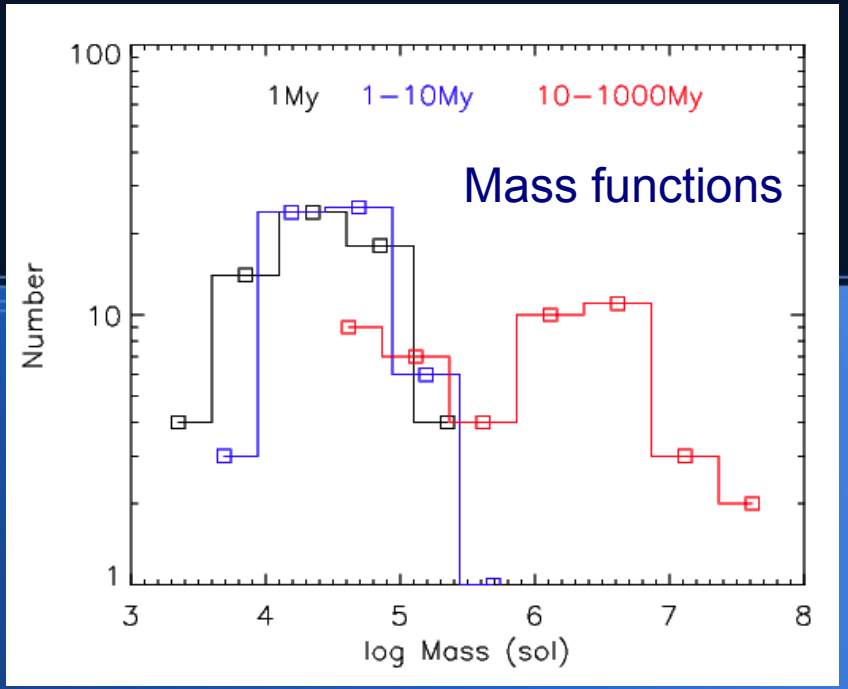

- Slopes in very high-SF galaxies are shallower than in "normal spirals"
- Evidence for environment dependent SSC disruption
- Mass functions next


$M_K = -2.51 \times \log(SFR) - 13.45$
Randriamanakoto et al. 2013b
$M_K^{brightest}$
log SFR
−19
−18
−17
−16
−15
1.0
1.2
1.4
1.6
1.8
2.0
Correlation between host SFR and brightest cluster.
Size-of-sample effect, or physics?

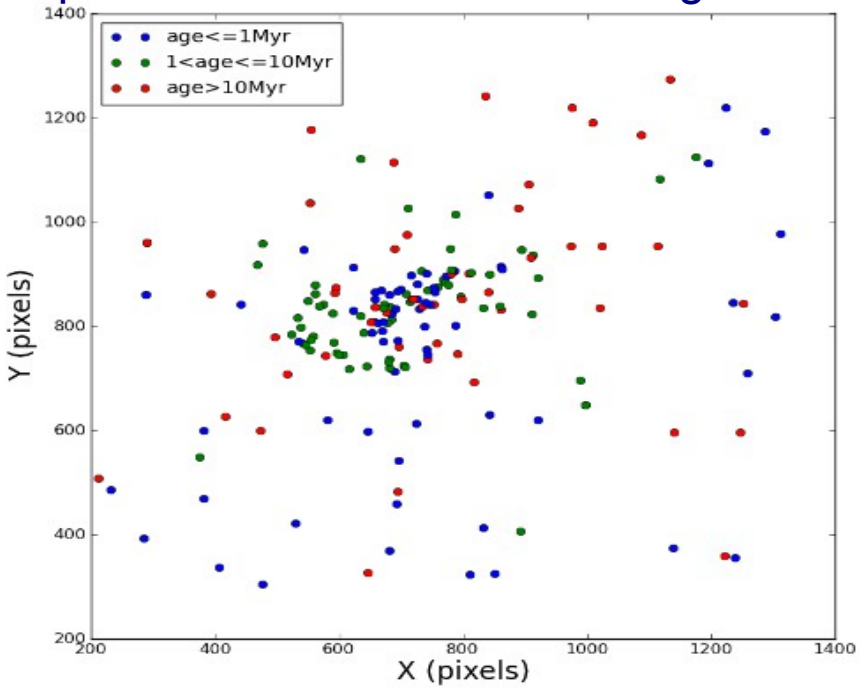
Thousands SSCs detected in VLT & HST images. Modelled using SB99, GALEV, and Zackrisson et al models.

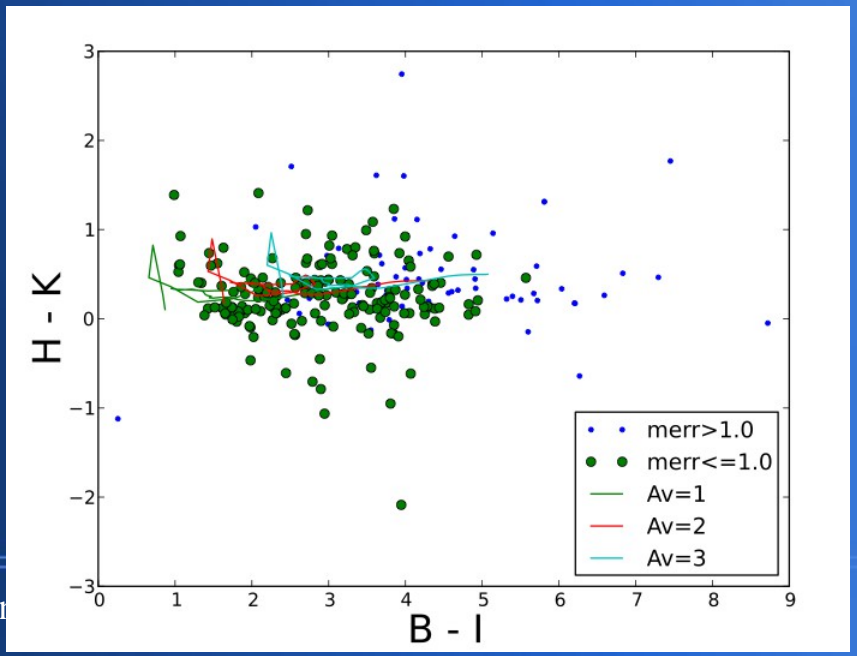
**SALT spectra crucial for extinctions and metallicity constraints**

[Randriamanakoto et al. 2014, in prep.]




Spatial distribution of various ages




Mafiker

# SALT spectroscopic work

Ongoing spectral follow-up with SALT (2011-2013). Whole sample with:

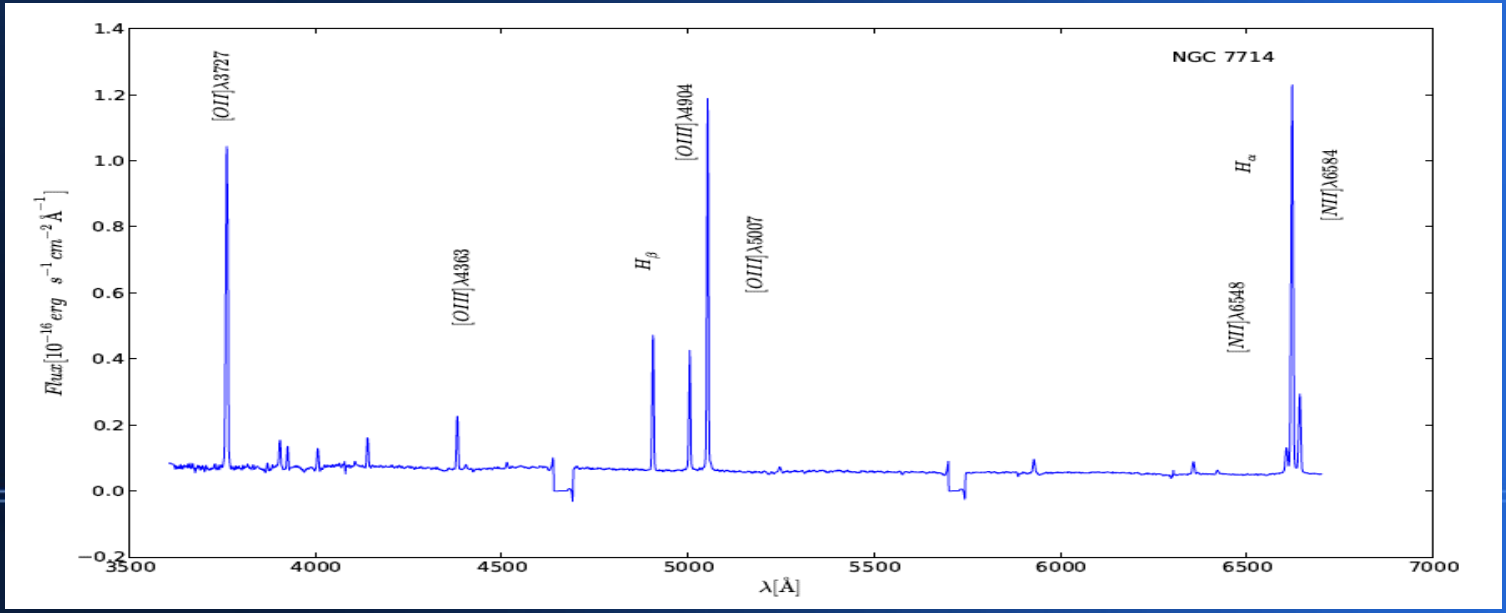
- PG900 (R~1000) for metallicities, extinctions and SP-fitting
- PG1800 (R~3000) at H and NaD for kinematics and gas inflows
- Fabry-Perot imaging spectroscopy in next step for most complex cases
- Stellar population modelling with UlySS (Koleva et al.) and Starlight (Cid Fernandes et al.)
- Kinematics and dynamical masses – helping to piece together history

# Morphologies and environment

- Confirming decrease of separation and increase of advanced mergers and remnants
- 40 % live in obvious major pairs
- At least 25% live in groups [Tekola+ 2012, 2013]. *None of these are ones in the final stages of merging.*
- Only 7% are totally “normal” isolated spirals.
- Another 30% also isolated, but 2/3 of these have complex cores (**minor mergers? Bar driven evolution?**) and 1/3 also tidal tails (merger remnants). **All are investigated in detail.**

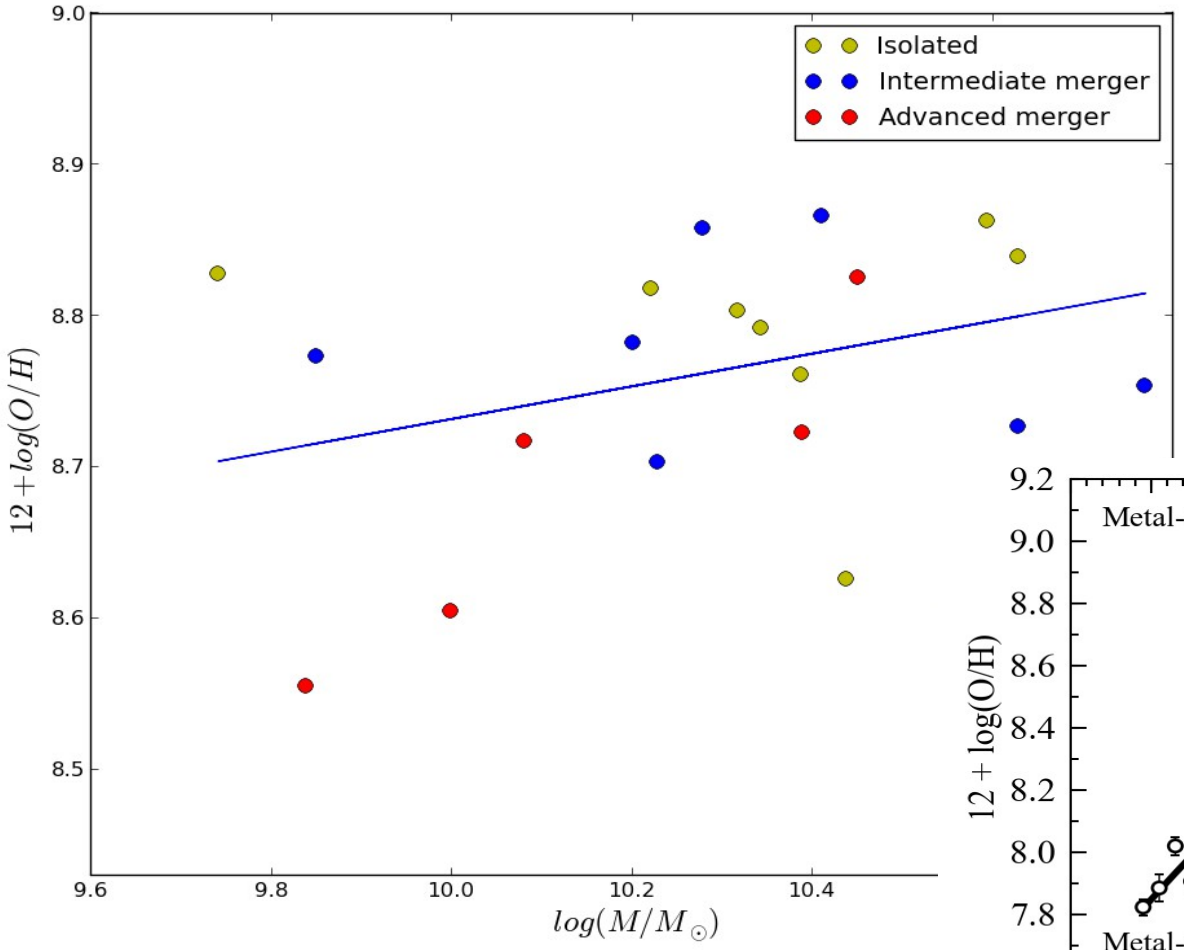
# Metallicities

- Central abundances are shown to be lower and gradients shallower in interacting pairs (Rupke et al. 2008, Rich et al. 2012). We can expand these studies quite significantly. Time scales and conditions of mixing?
  - We use direct methods (Kniazev et al.) if [OIII] λ4363 auroral line available (several lower metallicity cases do show it).
  - [OII] λ3727 often available, using calibrated $R_{23}$ – method and N2 and N2O3 methods for breaking degeneracies (eg. Kewley & Ellison 2008).

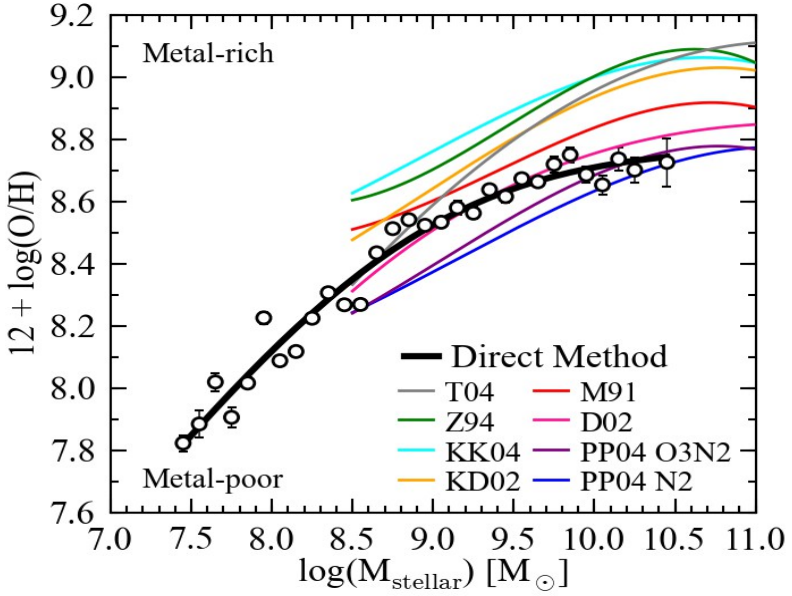


# Metallicities

Mass-metallicity relation. Scatter? Interaction? Mass?




[SDSS
Andrews, Martini, 03:]



Las Cumbres Observatory Global Telescope Network

LCOGT.net

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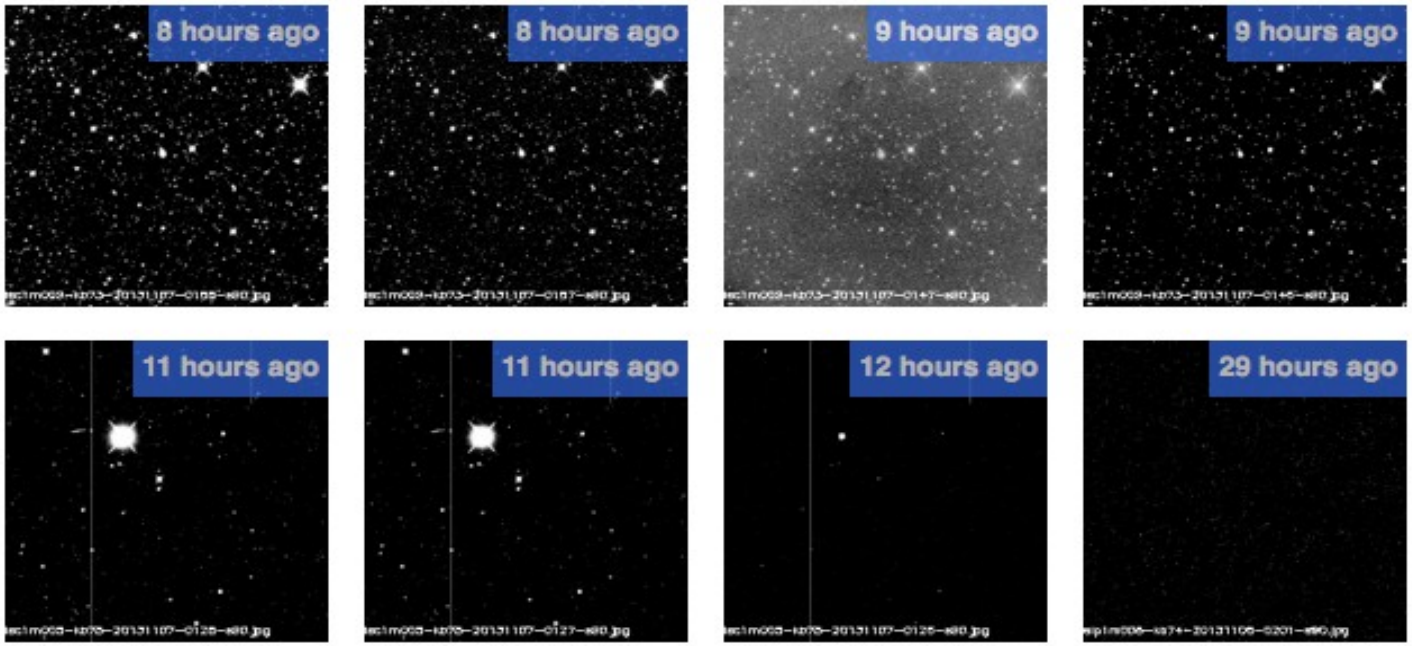
## Welcome Petri

[With Abiy Tekola]

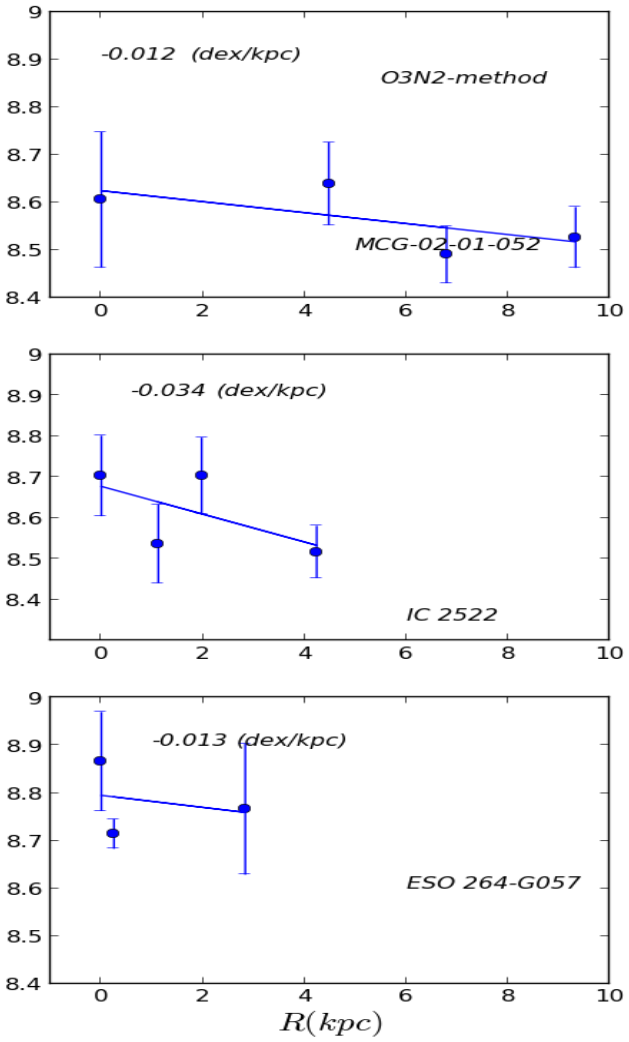
Proposals (1) | Observations (20)

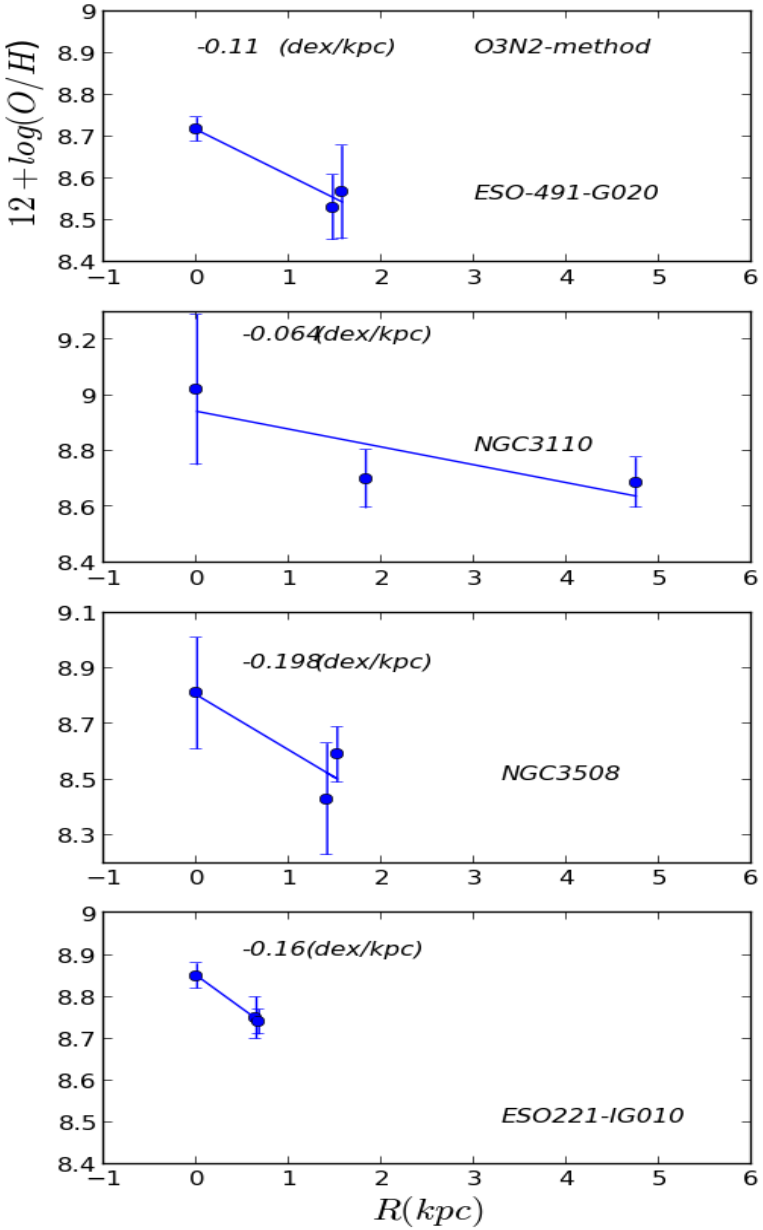
### Your proposals (1)

### Your recent observations



# Metallicity gradients

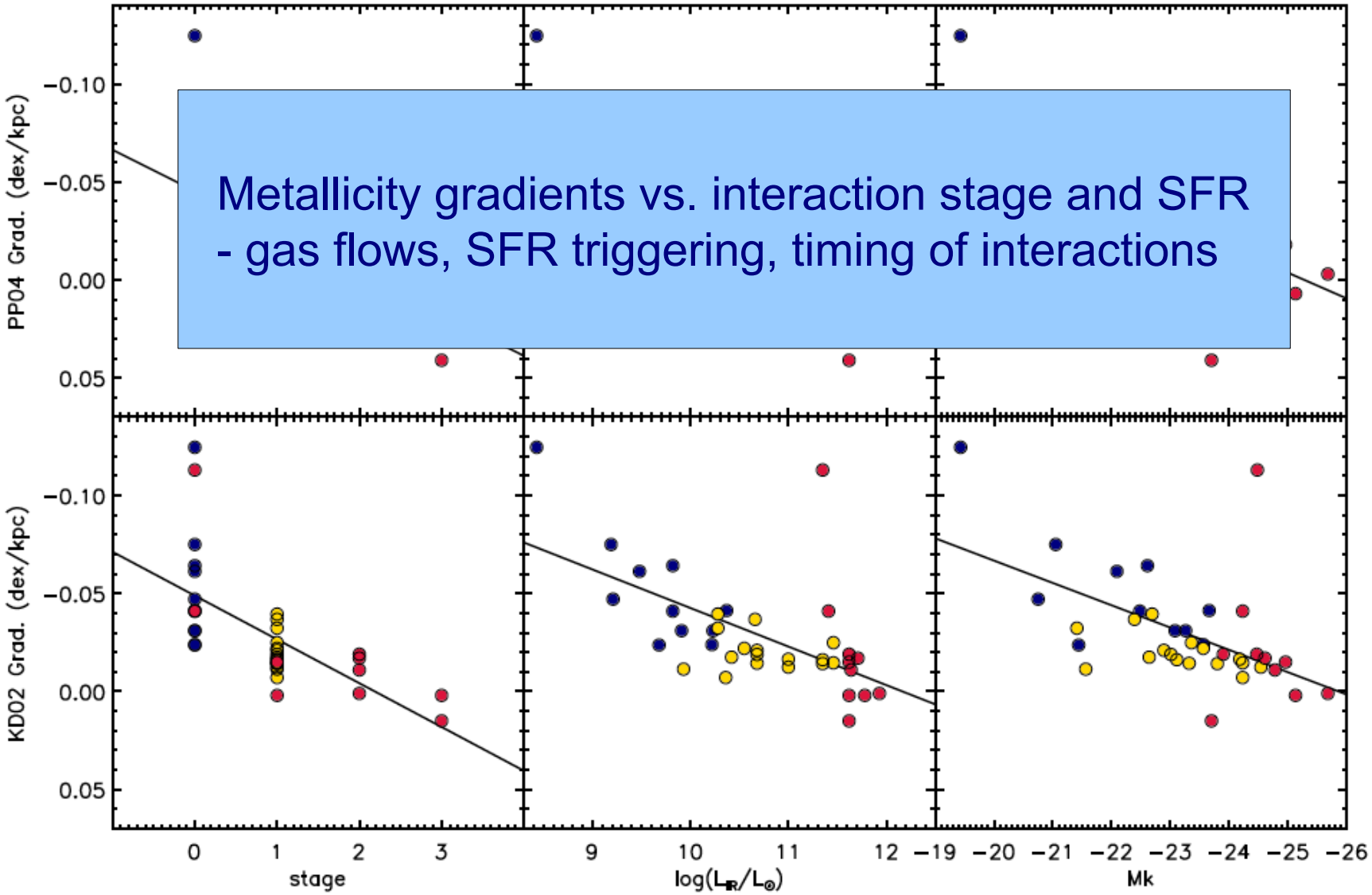


AN INTEGRAL FIELD STUDY OF ABUNDANCE GRADIENTS IN NEARBY LIRGS

J. A. Rich [1], P. Torrey[2], L. J. Kewley[1], M. A. Dopita[1,3,4], & D. S. N. Rupke[5]

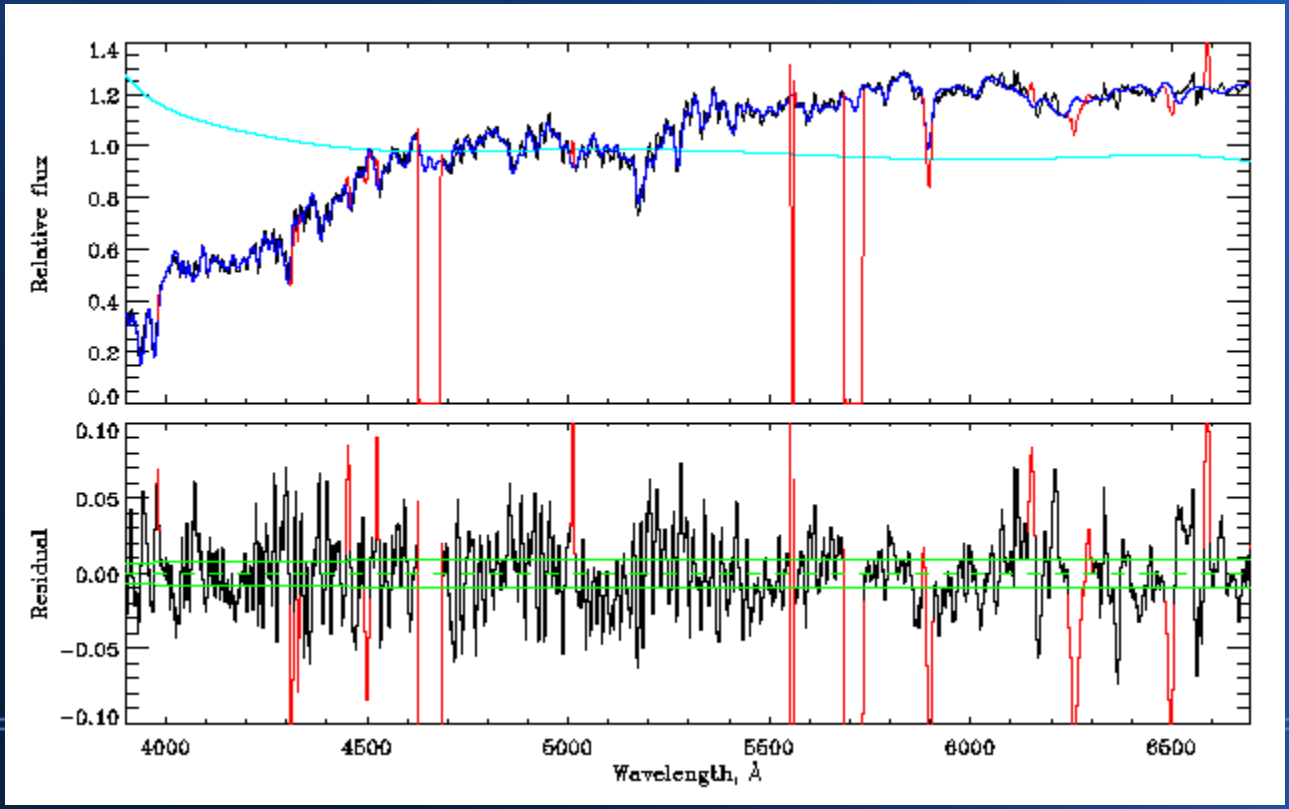
(Dated: April 26, 2012)




Metallicity gradients vs. interaction stage and SFR
- gas flows, SFR triggering, timing of interactions

# Stellar Populations

- Spatially resolved stellar population ages, metallicities, star-formation histories – starting with 'easier' galaxies, most LIRGs will have complicated histories (young + older)



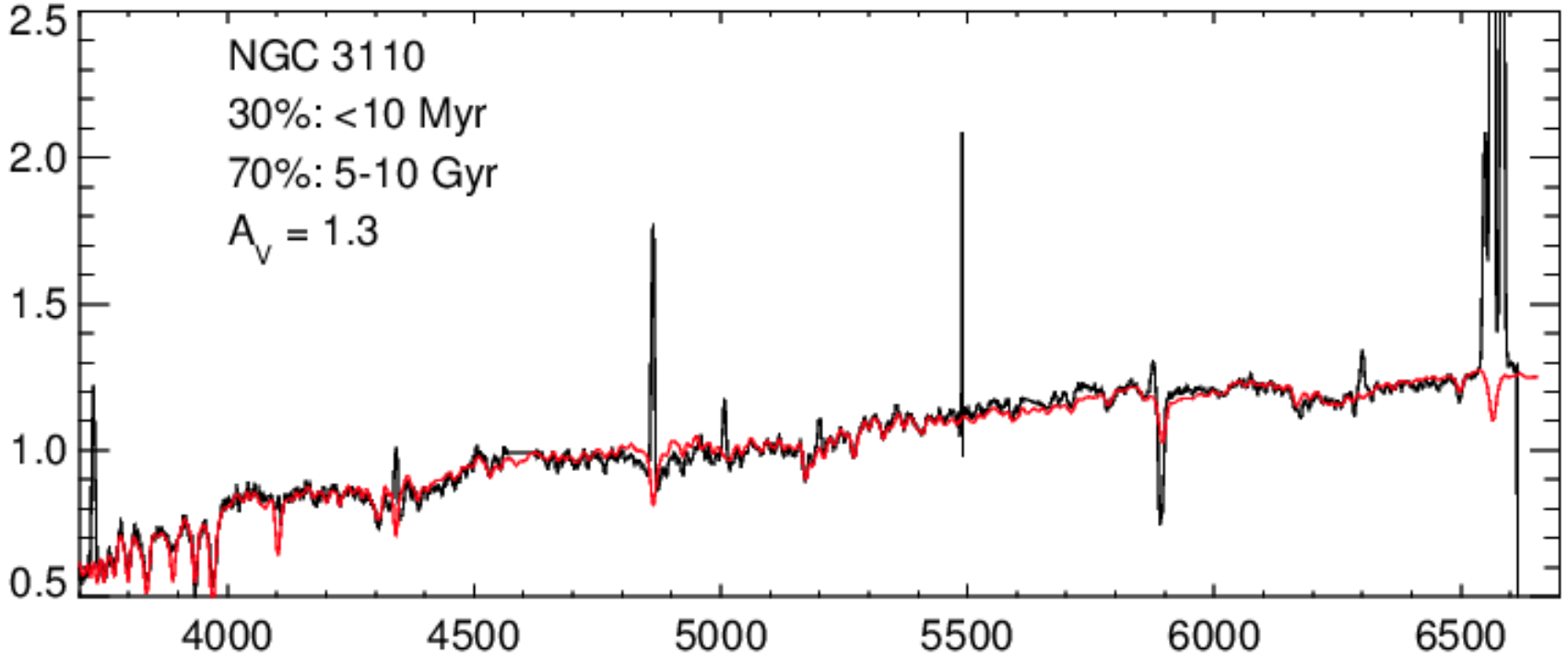

Using:

*UlySS* (Koleva et al.)

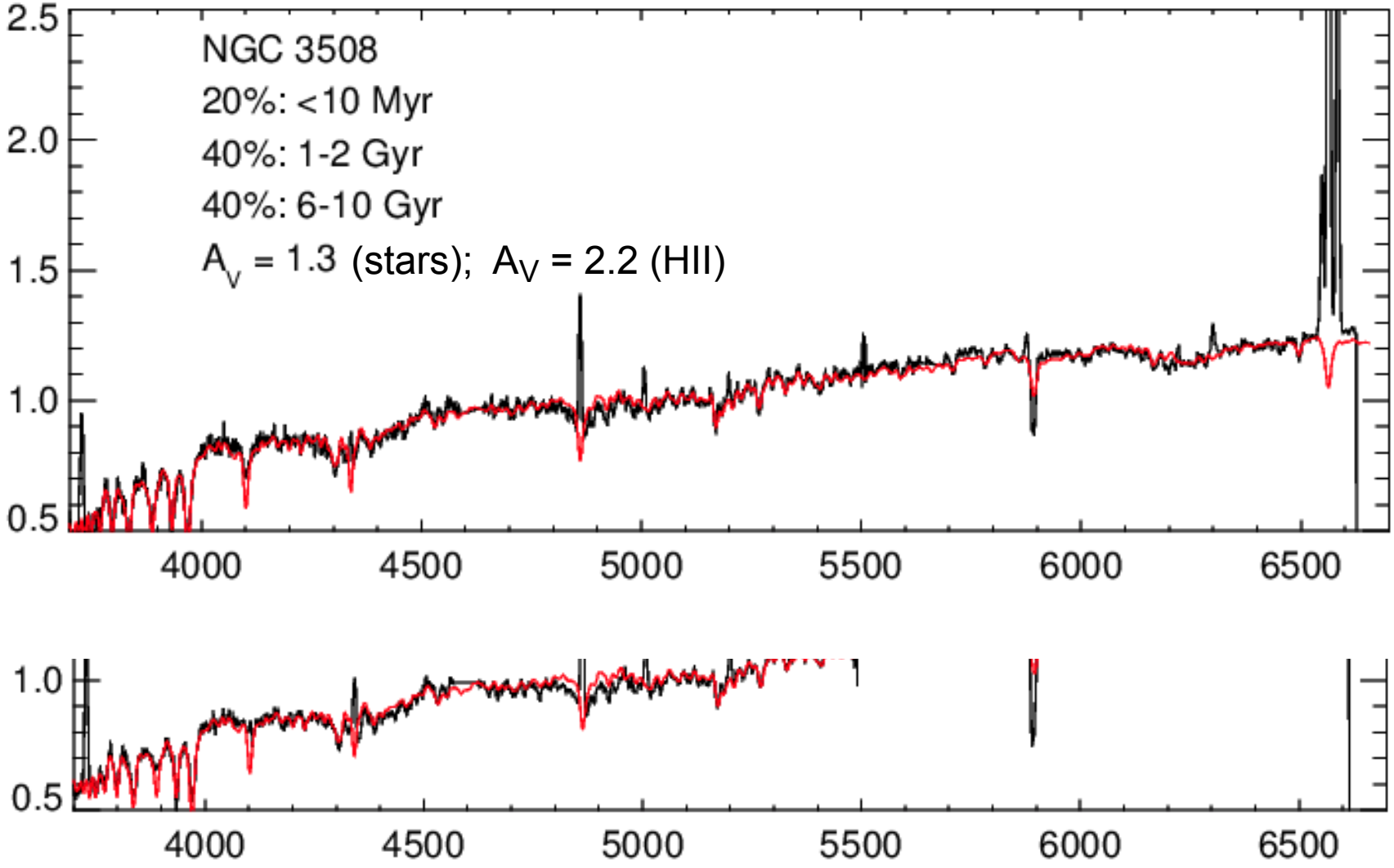
*Starlight* (Cid Fernandes et al.

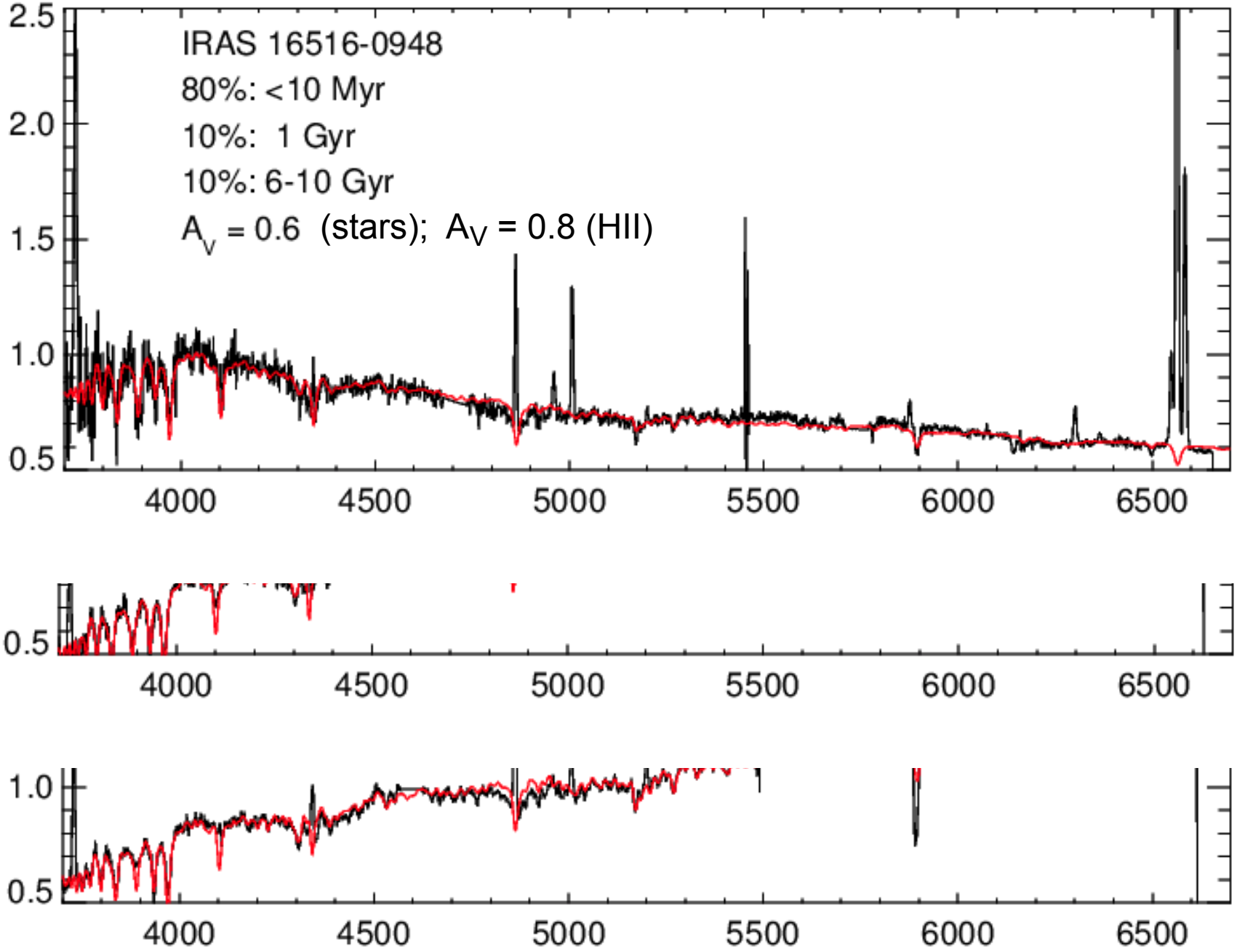
Continuum fits used to subtract stellar absorption from emission lines studies

# Stellar Populations



# Stellar Populations




IRAS 16516-0948
80%: <10 Myr
10%: 1 Gyr
10%: 6-10 Gyr
$A_V$ = 0.6 (stars); $A_V$ = 0.8 (HII)
2.5
2.0
1.5
1.0
0.5
4000
4500
5000
5500
6000
6500

# Stellar Populations

- Generally finding light dominated by < 50 Myr or < 10 Myr population, with a significant contribution by few x 100 Myr population.  And an old SP present as well.

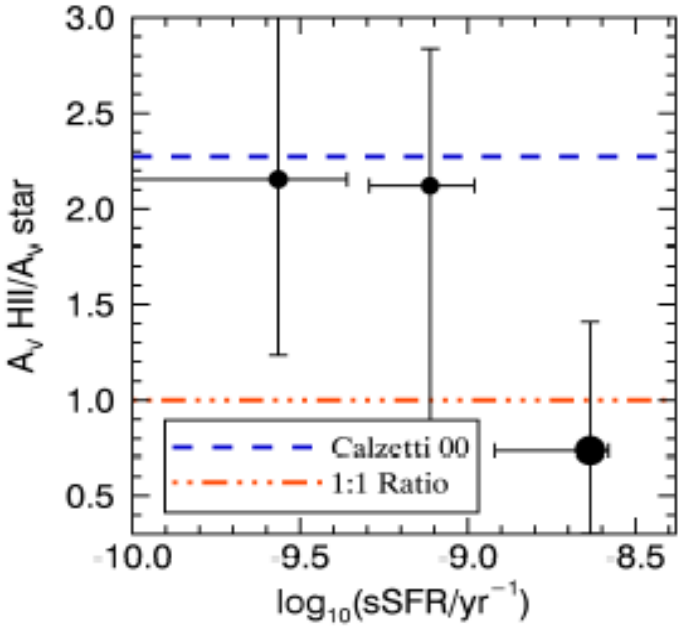
- Mass dominated by the very old population.

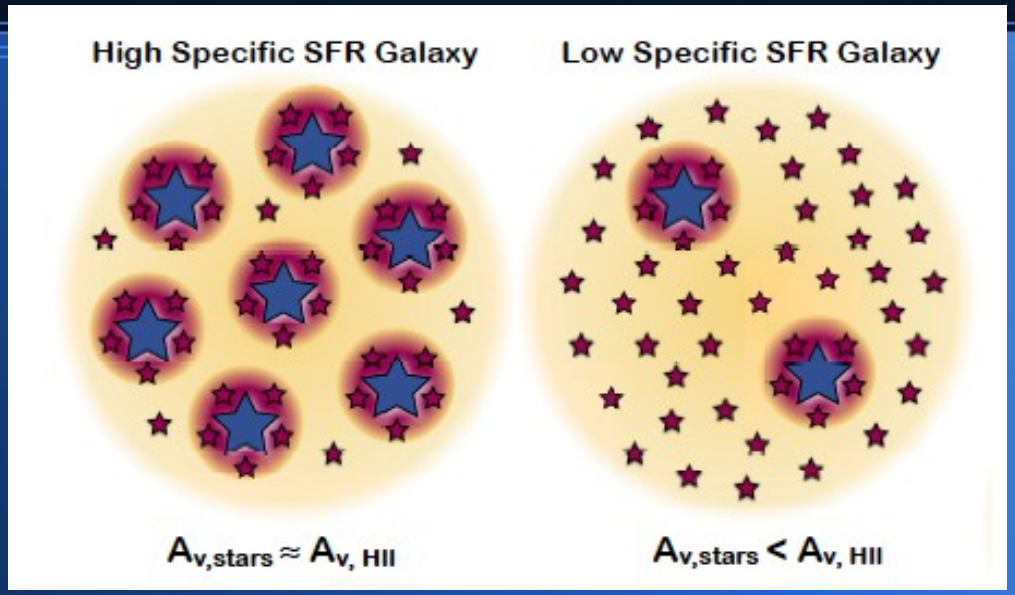
- SFH will be correlated with SSC ages as well as likely interaction stage scenarios.

- SP characteristics will have spatial resolution

# Dust geometry

Extinction of the *stellar populations* and the *HII regions* is often different.
(→ 2-component dust model)



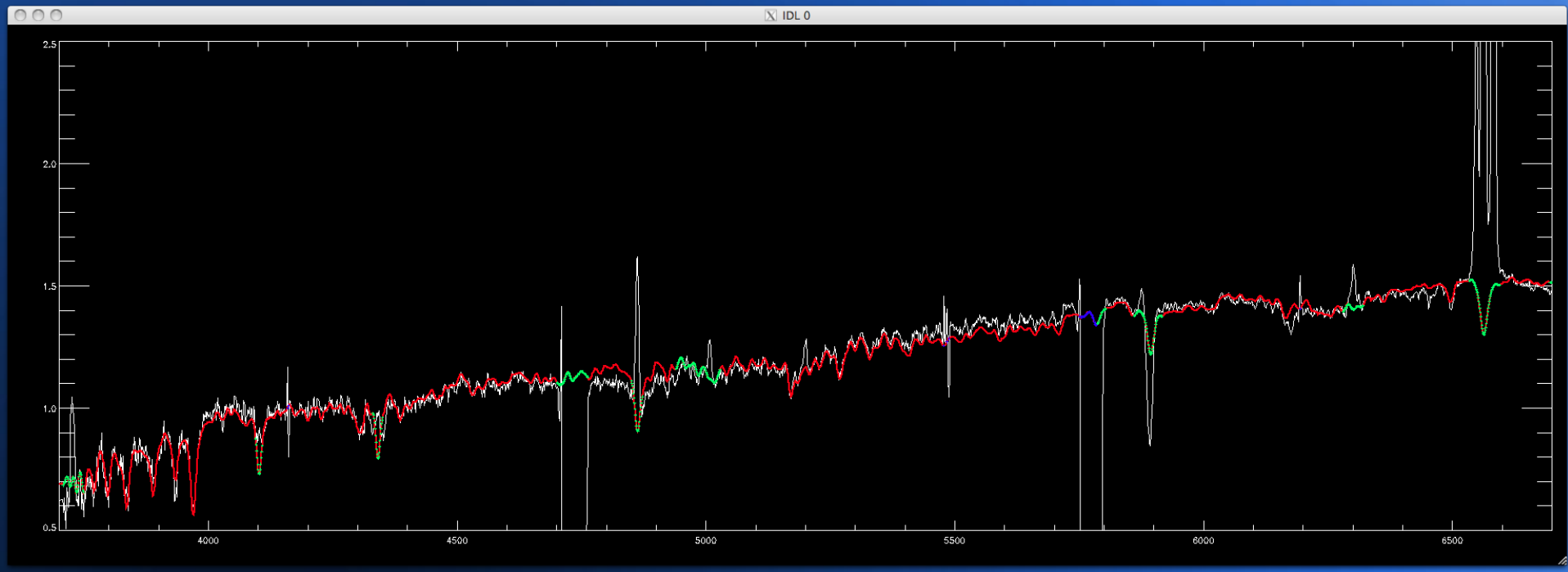




[Price et al 2013]

Differences will be correlated with SFR, mass, interaction stage – and especially the spatial information of the differences with the super star cluster distribution.

# Stellar Populations

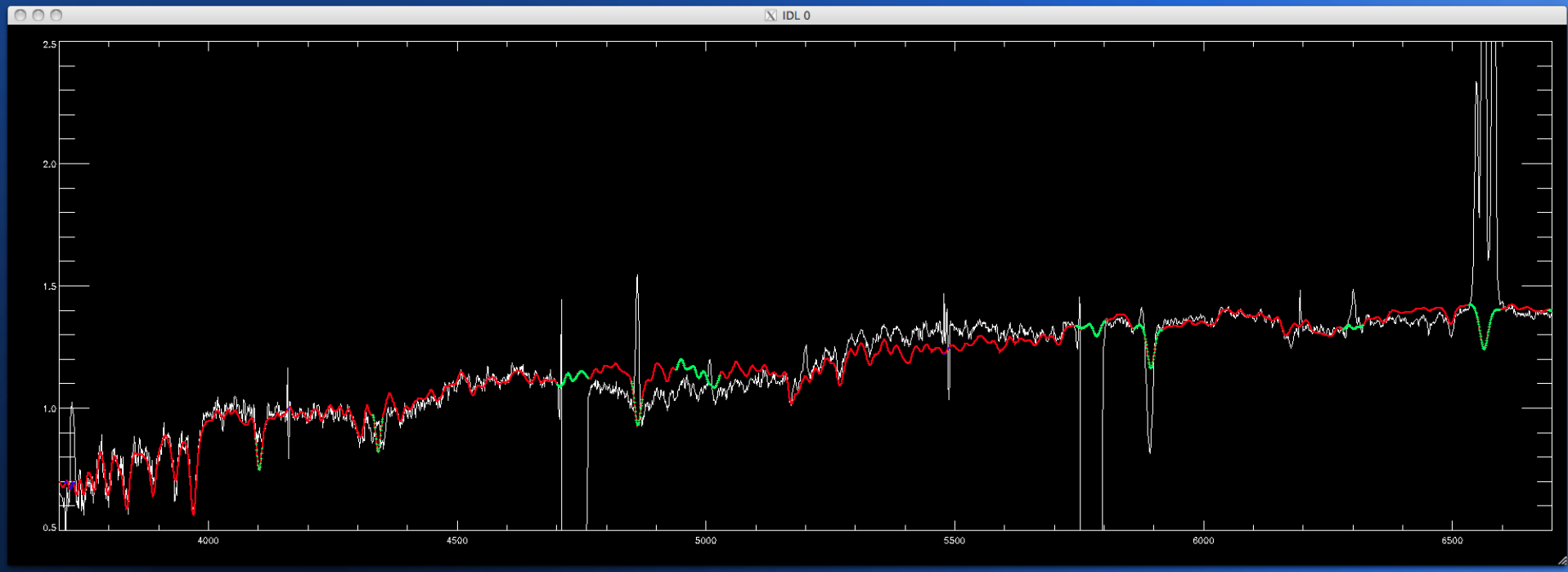
13th




Take care in fitting your spectrophotometric standard if interested in the continuum!

# Stellar Populations

5th

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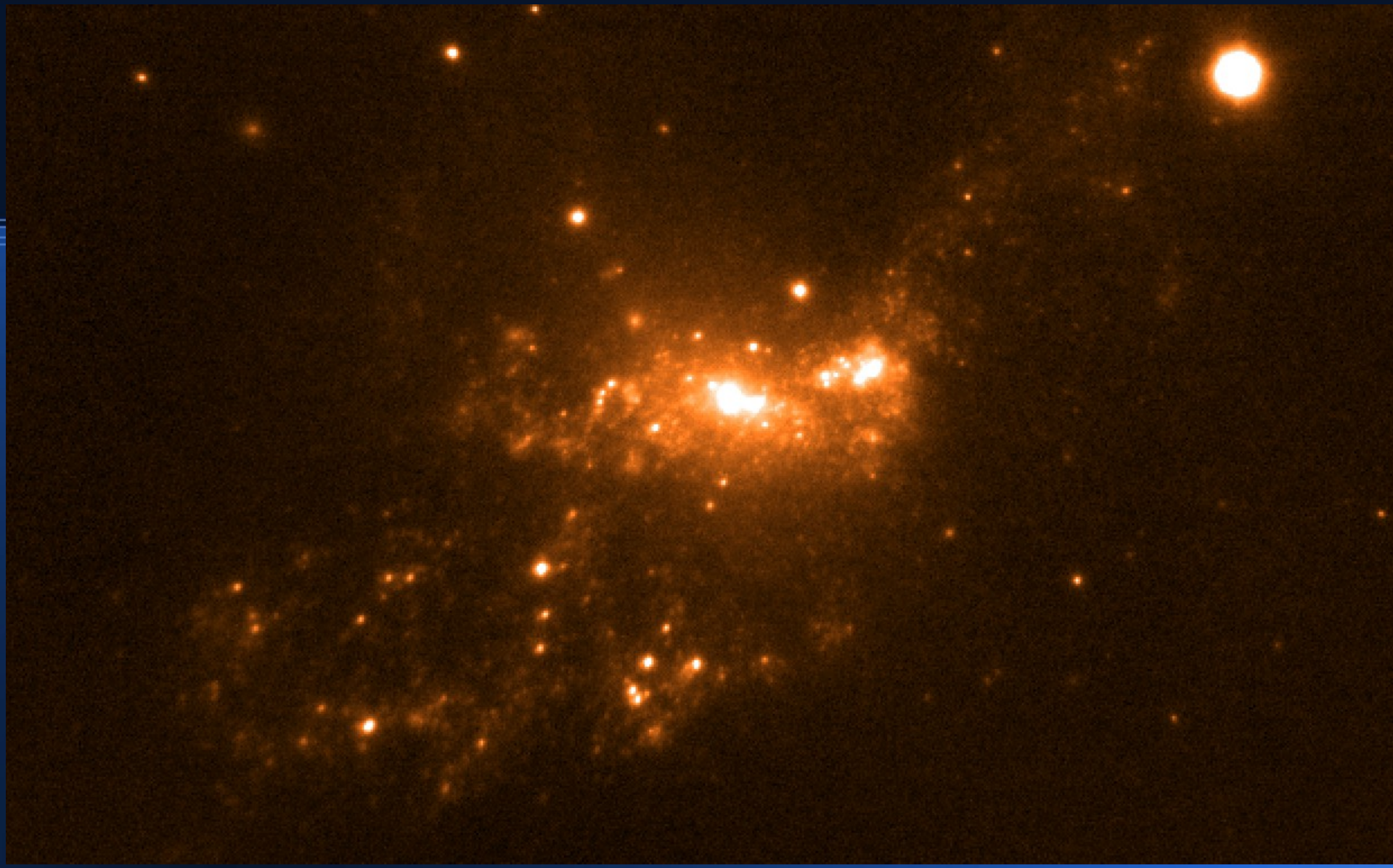
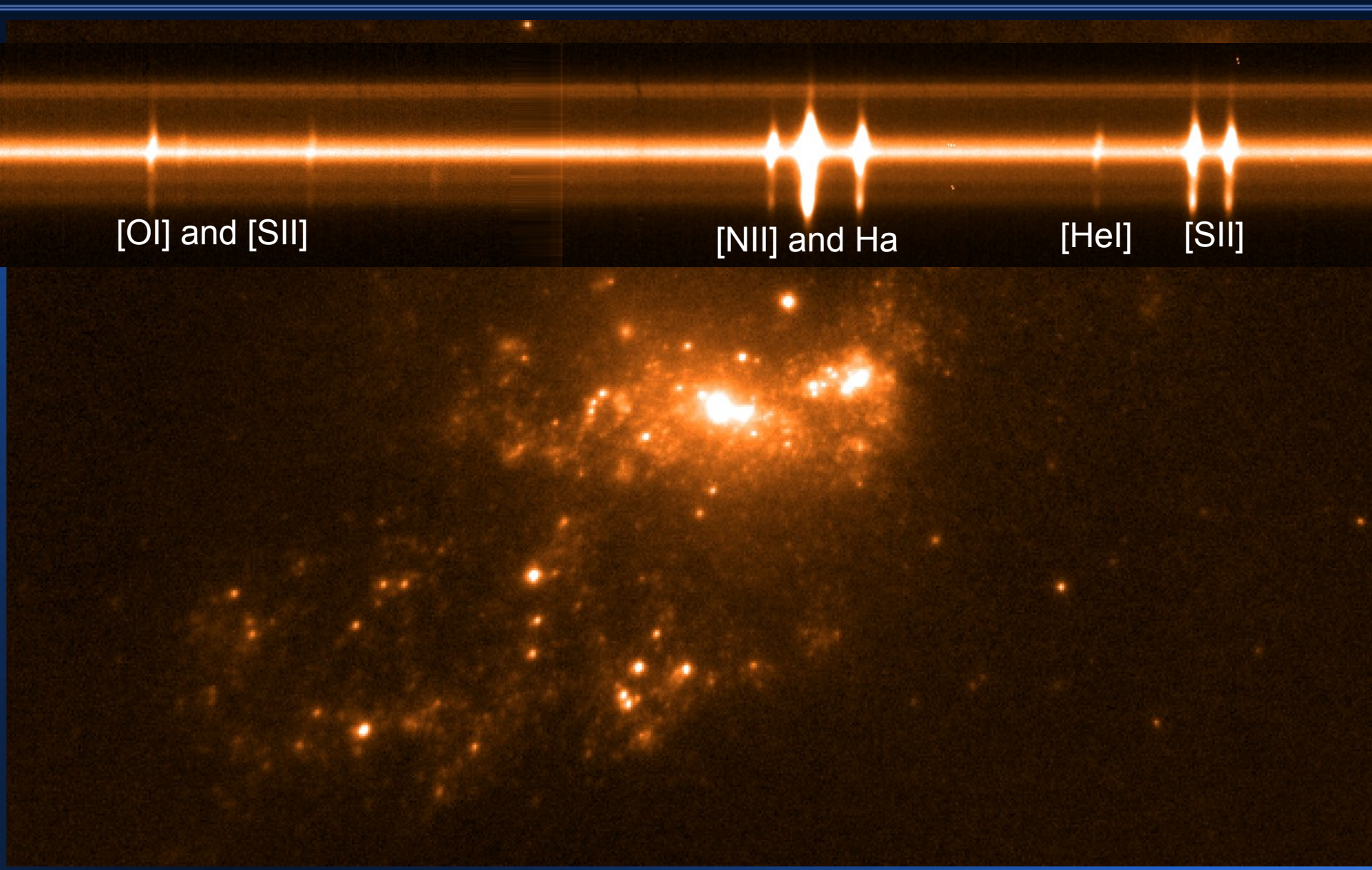


ESO 221-IG008

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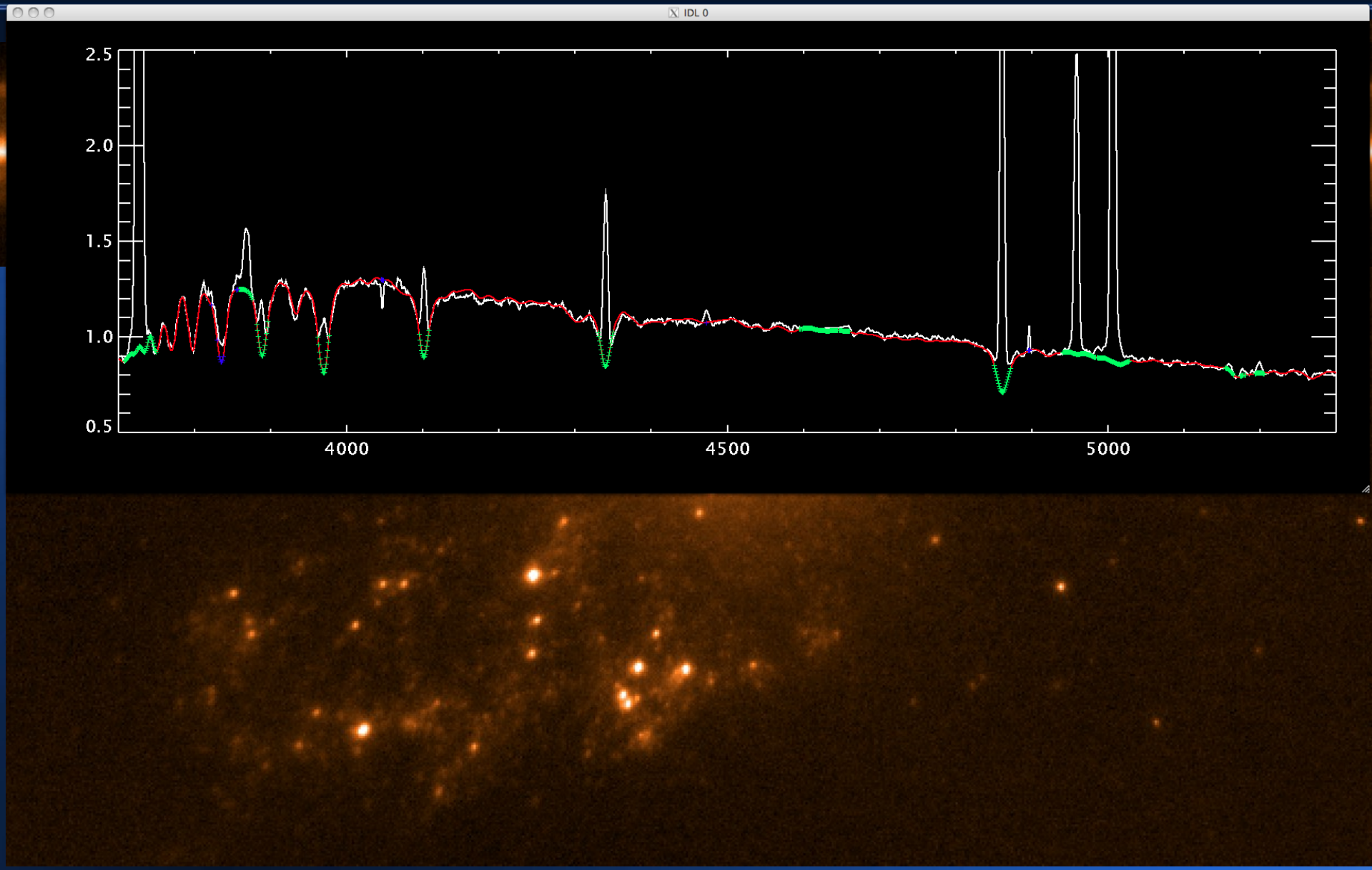


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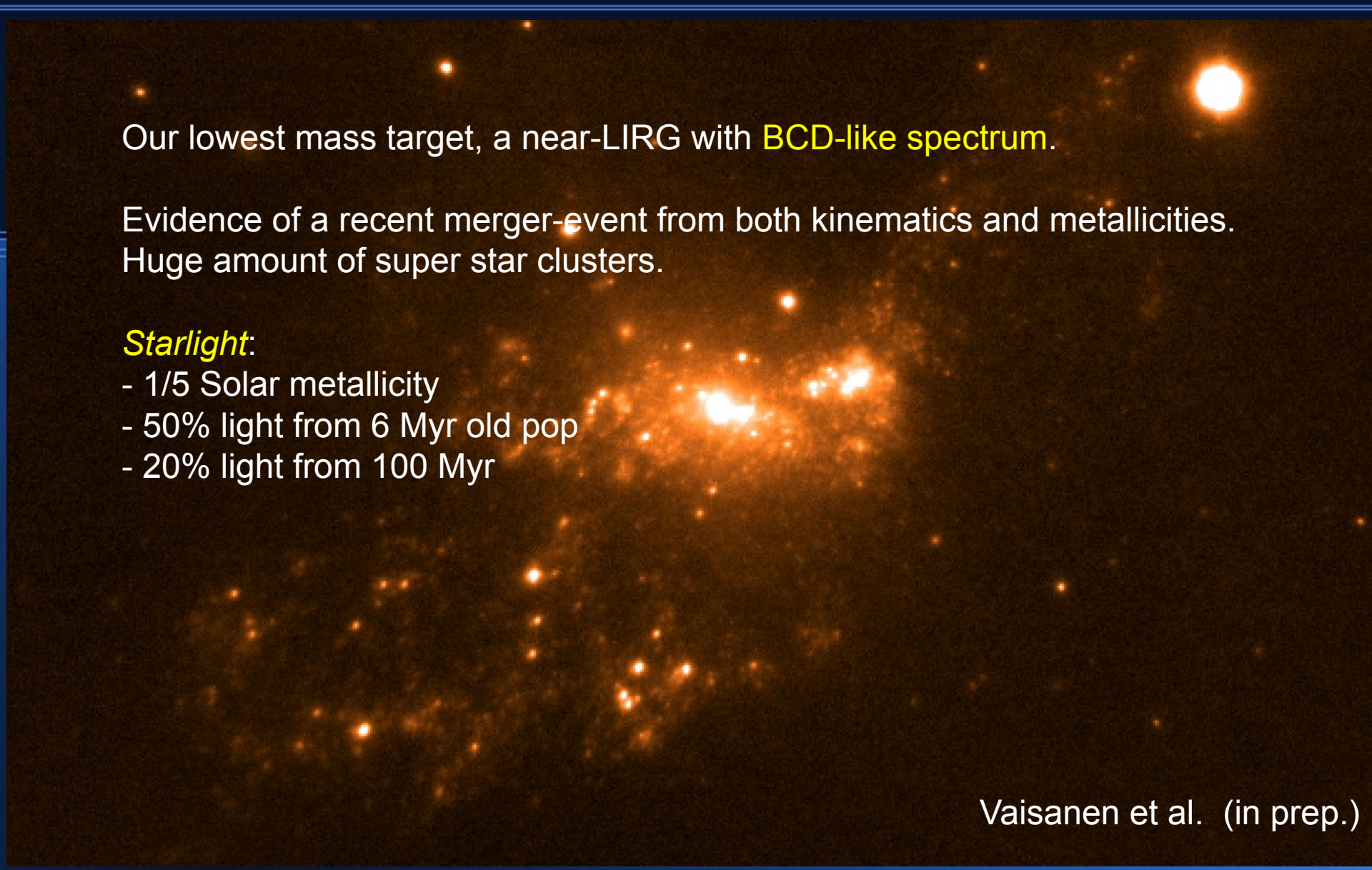


Our lowest mass target, a near-LIRG with BCD-like spectrum.

Evidence of a recent merger-event from both kinematics and metallicities.
Huge amount of super star clusters.

*Starlight*:
- 1/5 Solar metallicity
- 50% light from 6 Myr old pop
- 20% light from 100 Myr

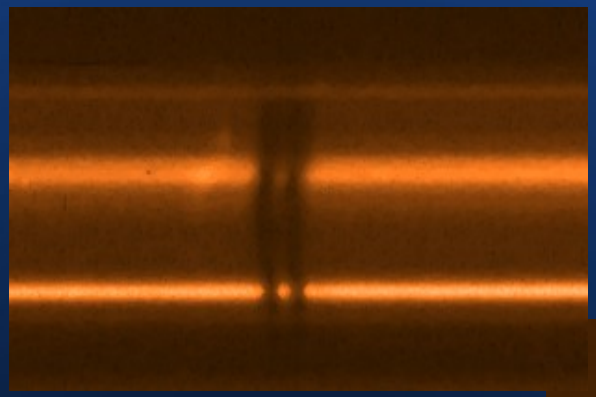
Vaisanen et al. (in prep.)

ESO 221-IG008

# Gas flows – example from IRAS 18293-3413

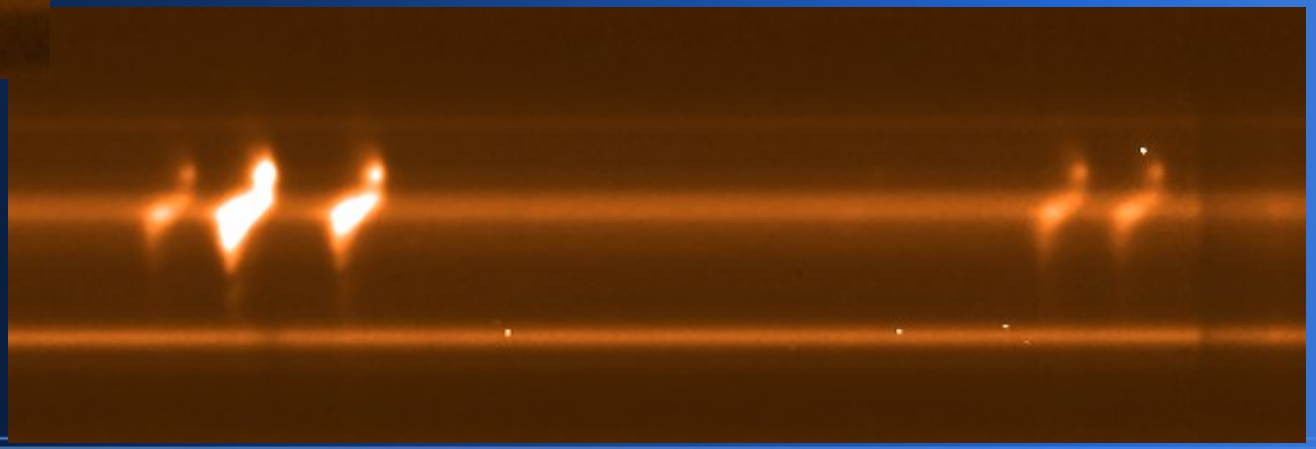
- SALT spectrum confirms minor companion, and shows very strong cool-gas motions, galaxy wide 10+ kpc scale winds. SSC triggered?

Vaisanen et al. (in prep.)

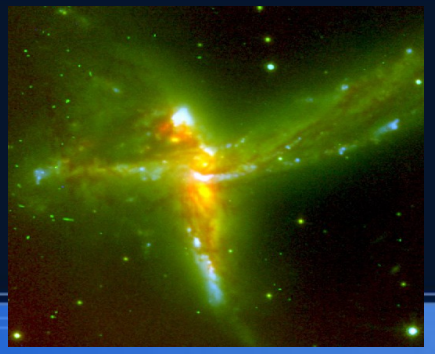


Na I D (and He I)

Hα, [NII] and [SII]



# Summary



- SUNBIRD - A survey of 40 LIRGs and 40 starbursts (**SALT**, VLT, Gemini, etc.) ongoing.
- Luminous IR-galaxies provide a lab to study a variety of key phenomena related to triggering of star-formation, SB vs. AGN activity in interactions, effects of feedback.
- Individual cases do not always easily fit the simplest “gas-rich spirals to obscured AGN to ellipticals” -scenarios.
- Evidence for groups and multiple-mergers having a significant impact on the end-results of the “merger sequence”.
- Super Star clusters vs. violent SF a tool to trace history of LIRGs